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Resonant Scattering in Delta-doped Heterostructures

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Resonant X-ray scattering was used in probing the structure of doping layers at a heterostructure interface. The positions of germanium layers inserted at the interface of a silicon epitaxial film assert a strong influence of the phase of the scattered intensity along the crystal truncation rods. The phase of the scattering, and hence the internal structure of the layers were determined by analyzing its energy-dependence in the vicinity of the Germanium absorption edge at 11.103keV.

Crystal truncation rods (CTRs) are continuous lines of diffracted intensity following the direction of the normal to a well-defined surface. Analysis of the distribution of intensity along CTRs yields interface structure at the atomic level. This method has been extensively used to reveal doping profiles in InAs/InPAs-type heterostructures, where the lattice distortions are minimal and only the chemical distribution can provide contrast.

The figure below shows the energy dependence measured at strategic positions along the crystal truncation rod, where the phase of the Si part of the structure takes very different values. The structure factor has been derived from the measured intensity. A linear correction for the variation of the monitor normalization with energy has been applied, the same for all curves. It is immediately obvious that the shape of the resonance is quite different for the four L-values shown. At certain L's the resonance appears as a step, up or down; at other L's it appears as a cusp, again either up or down. This is because the phase of the Si part of the structure factor selects various combinations of the real or imaginary part of the Ge atomic form factor in the sum. Apparently the shape of the resonance observed can be tuned continuously by the choice of perpendicular momentum transfer, L.

We calculated the energy-dependence of the structure factor, without adjusting any parameters, using a suitably modified version of “ROD”. The result is overlaid on the spectra of the figure. The curves are shifted by a scale factor as well as offset for clarity. The important point is that the general shapes of the resonances are well reproduced by the calculation.

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